

Parameter	Control	100 mg/kg	200 mg/kg	400 mg/kg	800 mg/kg
Body weight (g)	210.0 ± 10.0	210.0 ± 10.0	210.0 ± 10.0	210.0 ± 10.0	210.0 ± 10.0
Food intake (g)	10.0 ± 2.0	10.0 ± 2.0	10.0 ± 2.0	10.0 ± 2.0	10.0 ± 2.0
Water intake (ml)	5.0 ± 1.0	5.0 ± 1.0	5.0 ± 1.0	5.0 ± 1.0	5.0 ± 1.0
Urine volume (ml)	1.0 ± 0.2	1.0 ± 0.2	1.0 ± 0.2	1.0 ± 0.2	1.0 ± 0.2
Urine pH	7.0 ± 0.2	7.0 ± 0.2	7.0 ± 0.2	7.0 ± 0.2	7.0 ± 0.2
Urine creatinine (mg/dl)	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
Urine protein (mg/dl)	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.05	0.1 ± 0.05
Urine glucose (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine ketone (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine bilirubin (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine urobilinogen (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine hemoglobin (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine nitrite (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine leukocytes (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine erythrocytes (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine bacteria (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine fungi (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine parasites (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine mucus (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine crystals (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine sediment (mg/dl)	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Urine pH (range)	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5	6.5-7.5
Urine creatinine (range)	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6	0.4-0.6
Urine protein (range)	0.05-0.15	0.05-0.15	0.05-0.15	0.05-0.15	0.05-0.15
Urine glucose (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine ketone (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine bilirubin (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine urobilinogen (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine hemoglobin (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine nitrite (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine leukocytes (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine erythrocytes (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine bacteria (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine fungi (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine parasites (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine mucus (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine crystals (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0
Urine sediment (range)	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0	0.0-0.0

Attorney Docket No. LAM1P154

**PROCESS FOR ETCHING VIAS IN ORGANOSILICATE
GLASS MATERIALS WITHOUT CAUSING RIE LAG**

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Field of the Invention

The present invention relates to semiconductor or integrated circuit manufacture. More particularly, the present invention relates to the etching of features in integrated circuits. Still more particularly, the present invention relates to the manufacture of semiconductor devices including at least one layer of organosilicate glass dielectric have a feature formed therein by etching through the dielectric.

Background of the Invention

Integrated circuits use dielectric layers, which have typically been formed from silicon dioxide, SiO_2 , to insulate conductive lines on various layers of a semiconductor structure. As semiconductor circuits become faster and more compact, operating frequencies increase and the distances between the conductive lines within the semiconductor device decrease. This introduces an increased level of coupling capacitance to the circuit, which has the drawback of slowing the operation of the semiconductor device. Therefore, it has become important to use dielectric layers that are capable of effectively insulating conductive lines against such increasing coupling capacitance levels.

In general, the coupling capacitance in an integrated circuit is directly proportional to the dielectric constant, K , of the material used to form the dielectric layers. As noted above, the dielectric layers in conventional integrated circuits have traditionally been formed of SiO_2 , which has a dielectric constant of about 4.0. As a consequence of the increasing line densities and operating frequencies in semiconductor devices, dielectric layers formed of SiO_2 may not effectively insulate the conductive lines to the extent required to avoid increased coupling capacitance levels.

In an effort to reduce the coupling capacitance levels in integrated circuits, the semiconductor industry has engaged in research to develop materials having a dielectric constant lower than that of SiO_2 , which materials are suitable for use in forming the dielectric layers in integrated circuits. To date, a number of promising materials, which are sometimes referred to as "low-K materials", have been developed. Many of these new dielectrics are organic compounds.

One interesting class of organic low-K materials are compounds including organosilicate glass. By way of example, but not limitation such organosilicate dielectrics include CORAL™ from Novellus Systems, Inc. of San Jose, CA; Black Diamond™ from Applied Materials of Santa Clara, CA; and Sumika Film® available from Sumitomo Chemical America, Inc., Santa Clara, CA.

During semiconductor wafer processing, features of the semiconductor device have been defined in the wafer using well-known patterning and etching processes. In these processes a photo resist material may be deposited on the wafer and may then be exposed to light filtered by a reticle. The reticle may be a glass plate that is patterned with exemplary feature geometries that block light from propagating through the reticle.

The development of an effective etching process for an organosilicate glass low-K film such as CORAL™ should take into account several criteria including etch rate, profile control, selectivity to underlying materials as well as critical dimension (CD) control. The etching of low-K dielectric materials was at first approached as if a silicon-based dielectric were being etched. This has not proven particularly effective, as with organic low-K films the chemistries and processes needed to effectively etch the material are substantially different than those for traditional silicon or silicon oxide etching. This has proven even more problematic for the etching of organosilicate glass low-K films.

Organosilicate glass low-K films are often etched using etchant gas flows of similar chemical composition to other materials used in the semiconductor manufacturing process. This can render the manufacture of such devices difficult. As integrated circuits geometries continue to shrink, plasma etch processes are required to define these high resolution patterns. The most widely used dry etch technique is

Reactive Ion Etching, or RIE, which offers directionality and selectivity together with high throughput.

The etching of high aspect ratio trenches, sometimes referred to as HART, into OSG and other low-K materials is becoming increasingly important for micro- and nano-engineering. One example is in the case of comb-driven structures, trench capacitors, and trench isolation for vertical transistors. The aspect ratio, AR, is defined as the depth of the trench divided by its width. Currently, one of the most commonly implemented techniques for etching HART's is dry reactive ion etching, or RIE.

When etching HART's with RIE it is observed that the etch rate is dependant on time and the mask opening. In general, smaller trench openings are etched more slowly than those which are wider. Accordingly, large features etch at a faster rate than small features. This effect is known as RIE lag and apparently depends on the AR of the trench rather than on the depth or width of the trench.

Prior efforts at etching vias and other structures in wafers incorporating OSG have generally utilized some form of $\text{Ar}/\text{C}_4\text{F}_8/\text{O}_2$ etch chemistry. In general, these attempts have met with poor results. Many of these different processes resulted in either severe reverse RIE lag, poor via profiles, nonuniformity at high etch rates, or poor resist selectivity.

What is needed is a process chemistry for etching features in wafers incorporating OSG dielectrics which process results at once in minimal RIE lag, minimal bowing of the features formed by the etch process, good etch profiles, good resist selectivity, and good etch uniformity across the wafer.

It would be desirable if the methodology were capable of implementation on existing semiconductor etch equipment.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2
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Brief Description of the Drawing

For more complete understanding of the present invention, reference is made to the accompanying Drawing in the following Detailed Description of the Invention. In the drawing:

5 Fig. 1a is a flowchart representation of one embodiment of the present invention.

 Fig. 1b is a flowchart representation of an alternate embodiment of the present invention, including an in site photoresist strip step.

10 Fig. 2a is a cross section through an example wafer stack, including a layer of patterned photoresist, prior to etching according to one embodiment of the present invention.

 Fig. 2b is a cross section through the example wafer stack, after a first etch step performed in accordance with one embodiment of the present invention.

15 Fig. 2c is a cross section through the example wafer stack, after a second etch step performed in accordance with one embodiment of the present invention.

 Fig. 2d is a cross section through the example wafer stack, after a third etch step performed in accordance with one embodiment of the present invention.

20 Fig. 2e is a cross section through the example wafer stack, after all etching has performed in accordance with one embodiment of the present invention, and following in situ stripping of the photoresist layer.

 Reference numbers refer to the same or equivalent parts of the invention throughout the several figures of the Drawing.

Detailed Description of the Preferred Embodiments

The present invention teaches a novel etch chemistry for etching a wide variety of feature sizes and shapes in wafers incorporating blank dielectrics. The methodology taught herein results in minimal RIE lag, minimal bowing of the vias formed by the etch process, good etch profiles, good resist selectivity, and good etch uniformity across the wafer.

Prior efforts at etching vias in OSG have generally utilized some form of Ar/C₄F₈/O₂ etch chemistry. In general, in these attempts have met with four results. Many of these different processes resulted in either severe reverse RIE lag, poor via profiles, nonuniformity at high etch rates, or poor resist selectivity.

In order to etch a variety of feature sizes, including but specifically not limited to trenches and vias, in wafers including organosilicate dielectric layers the present invention implements an etchant mixture including octafluorocyclobutane, C₄F₈ and tetrafluoromethane, CF₄. One embodiment of the present invention implements an etchant mixture including Ar, oxygen, difluoromethane, and octafluorocyclobutane.

Having reference to Fig. 1a, in order to practice the present invention a wafer is situated within a reaction vessel capable of forming and etch plasma. This reaction vessel or chamber may be an item of single purpose etching equipment, or may be a multiple purpose wafer processing system. One equipment particularly well suited for practicing the present invention is the Exelan™ system dry etch system, available from Lam Research Corporation, Fremont, CA. Exelan™ is capable of performing hardmask open, inorganic and organic ARC etch, and photoresist strip in situ within a single chamber.

The wafer, previously having had a layer of patterned photoresist applied to let upper surface thereof, is mounted within the chamber, and an etch plasma struck. A flow of etchant gas is introduced into the chamber, 3. As previously discussed, this etchant gas comprises a mixture including argon, oxygen, difluoromethane, and octafluorocyclobutane.

The present invention may conveniently be implemented as part of a multi-step etch regime, for instance as shown at figures 1 and 2. Having reference now to Fig.2 a, an example wafer, 1, having a patterned layer of photoresist, 10, is shown. In this example, wafer 1 includes a silicon substrate, 22 having deposited thereon a

silicon carbide barrier layer, 20. Deposited over barrier layer 20 is a first layer 18 of organosilicate dielectric, for instance Coral™. A thin silicon carbide trench stop layer 16, is disposed between first blank layer 18, and a second blank layer, 14, also of Coral™ deposited over trench stop layer 16. A hard mask layer of PEARL™, a plasma-enhanced anti-reflective layer also available from Novellus Systems, Inc. San Jose, CA is deposited over second organosilicate layer 14, completing the example in wafer stack.. Patterned photoresist layer 10, previously discussed, is applied over hard mask 12.

Referring now to Fig. 2a and having continued reference to Fig. 1a, the effect of step 3 of Fig. 1a the shown. At this point, the previously discussed etch step implementing the etch mixture including Ar, oxygen, difluoromethane, and octafluorocyclobutane is performed utilizing the dual-frequency etch equipment previously discussed.

According to one embodiment of the present invention, a first, selective, etch step is conducted at a chamber pressure of between 0 and 250 mTorr, more preferably between 10 and 100 mTorr, more preferably still between 20 and 80 mTorr, and most preferably at about 60 mTorr. The upper frequency of the plasma is formed at power levels from about 250W to about 2500W. More preferably, the upper power level is formed from about 500W to about 2000W. More preferably still, this power level is set at between about 1000 to about 2000W. Most preferably the upper frequency power is set at about 1500W. The lower frequency power level is set at power levels from about 250W to about 2500W. More preferably, the upper power level is formed from about 500W to about 2000W. More preferably still, this power level is set at between about 1000 to about 2000W. Most preferably the upper frequency power is set at about 1100W.

The mixture of etchant gas is preferably comprised of flows of the constituent etch gasses. These include argon at flows from about 20 SCCM to about 300 SCCM, more preferably from about 50 SCCM to about 200 SCCM, more preferably still from about 100 SCCM to about 200 SCCM and most preferably at about 160 SCCM. The etchant gas also contains a flow of oxygen from about 1 SCCM to about 50 SCCM, more preferably from about 3 SCCM to about 30 SCCM, more preferably still from about 5 SCCM to about 20 SCCM and most preferably at about 10 SCCM.

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The etchant further includes the flow of difluoromethane, CH₂F₂, previously discussed, from about 1 SCCM to about 50 SCCM, more preferably from about 3 SCCM to about 30 SCCM, more preferably still from about 5 SCCM to about 20 SCCM and most preferably at about 7 SCCM. Also included is a flow of
5 octafluorocyclobutane, C₄F₈, also discussed previously and at a flow rate from about 1 SCCM to about 50 SCCM, more preferably from about 2 SCCM to about 30 SCCM, more preferably still from about 4 SCCM to about 20 SCCM and most preferably at about 5 SCCM. A final etch gas constituent in this embodiment is CF₄, tetrafluormethane at a flow rate from about 1 SCCM to about 50 SCCM, more
10 preferably from about 2 SCCM to about 30 SCCM, more preferably still from about 4 SCCM to about 20 SCCM and most preferably at about 5 SCCM.

Etching proceeds at a controlled temperature, for a specified period of time. In the exemplar under discussion, processing may proceed at temperatures between 0C and 50C. More particularly from about 5C to about 40C. More particularly still, from
15 about 10C to about 30C, and most preferably at about 20C. Process times may vary from small fractions of a second to about 10 minutes. In the example presented here, processed at the most preferable power settings, gas flows and temperature, processing was accomplished in about 75 seconds. This etch step provides a high degree of selectivity between the organosilicate dielectric 14 and the stop layer 16.

20 In order to accomplish the preceding temperature control, the temperature of the wafer is thermally maintained by a flow of coolant gas through the chuck retaining the wafer in the reaction vessel. This flow of coolant gas, for instance helium, is at a flow rate from about 1 SCCM to about 50 SCCM, more preferably from about 2 SCCM to about 30 SCCM, more preferably still from about 10 SCCM to about 20
25 SCCM and most preferably at about 15 SCCM.

At this point in the etch regime, the features, for instance 24 and 26, defined by photoresist layer 10 have now been etch through the first line layer, 14, and etching has stopped at the trench stop layer 16. In order to etch through trench, or etch stop layer 16, a second etch step, 4, is now performed.

30 According to the embodiment of the present invention, a second, low selectivity etch step is conducted at a chamber pressure of between 0 and 250 mTorr, more preferably between 10 and 100 mTorr, more preferably still between 20 and 80



mTorr, and most preferably at about 70 mTorr. This etch step provides a low degree of selectivity between the organosilicate dielectric and the SiC stop layer.

To perform this step, the upper frequency of the plasma is formed at power levels from about 250W to about 2500W. More preferably, the upper power level is formed from about 500W to about 2000W. More preferably still, this power level is set at between about 1000 to about 2000W. Most preferably the upper frequency power is set at about 1500W. The lower frequency power level is set at power levels from about 50W to about 1500W. More preferably, the lower frequency power level is formed from about 100W to about 1500W. More preferably still, this power level is set at between about 250 to about 1000W. Most preferably the lower frequency power is set at about 500W. This etch step provides a low degree of selectivity between the organosilicate dielectric 14 and the stop layer 16.

When the etch stop layer has been etched through, as shown at Fig. 2c, a third, selective etch step is performed, as shown at 5. According to the example wafer stack discussed herein, where the composition and thickness of second organosilicate dielectric layer 14 and first organosilicate dielectric layer 18 are substantially identical, this third etch step is likewise substantially identical to the first etch step. Process time may vary slightly between the first and third etch steps depending on the amount of the second organosilicate dielectric layer which has been previously etched during step 4. Etch step 5 is completed when barrier 20 is reached, as shown at figure 2d. Again, this etch step provides a high degree of selectivity between the organosilicate dielectric 18 and the stop layer 16.

A further alternative embodiment of the present invention contemplates the in situ stripping of the photoresist mask, 10. This embodiment is shown at Fig. 1b. Following the third etch step, 5, photoresist mask 10 is stripped as follows:

According to this embodiment of the present invention, an in situ photoresist strip step, 7, is conducted at a chamber pressure of between 10 and 1000 mTorr, more preferably still between 100 and 500 mTorr, and most preferably at about 330 mTorr. The upper frequency of the strip plasma is formed at power levels from about 25W to about 1000W. More preferably, the upper power level is formed from about 100W to about 500W. Most preferably the upper frequency power is set at about 200W. The lower frequency power level is set at power levels from about 0W to about 500W.

More preferably, the upper power level is formed from about 50W to about 250W.
Most preferably the upper frequency power is set at about 100W.

The mixture of stripping gas is preferably comprised of flows of the constituent strip gasses. These include oxygen at flows from about 10 SCCM to about
5 2000 SCCM, more preferably from about 100 SCCM to about 2000 SCCM, more preferably still from about 500 SCCM to about 1500 SCCM and most preferably at about 1000 SCCM. The etchant gas also contains a flow of nitrogen from about 1 SCCM to about 500 SCCM, more preferably from about 50 SCCM to about 300 SCCM, more preferably still from about 75SCCM to about 250 SCCM and most
10 preferably at about 200 SCCM.

Stripping also proceeds at a controlled temperature, for a specified period of time. In the exemplar under discussion, stripping may proceed at temperatures between 0C and 50C. More particularly from about 5C to about 40C. More particularly still, from about 10C to about 30C and most preferably at about 15C.
15 Process times may vary from small fractions of a second to about 10 minutes. In the example presented here, processed at the most preferable power settings, gas flows and temperature, processing was accomplished in about 40 seconds. This etch step provides a high degree of selectivity between second organosilicate dielectric 14 and stop layer 16.

20 At this point, the previously discussed etching and stripping steps have been completed, features 24 and 26 formed in wafer stack 1, and photoresist layer 10 stripped from that wafer stack. The wafer stack is now ready for further patterning, doping or deposition steps as required to complete the integrated circuit device.

A specific feature of the present invention is its novel ability to form features
25 of widely varying size contemporaneously, with excellent profile control and with minimal RIE lag, minimal bowing of the vias formed by the etch process, good etch profiles, good resist selectivity, and good etch uniformity across the wafer.

It will be apparent to those having ordinary skill in the art that the previously discussed power levels, pressures, flow rates, and temperatures are by way of example
30 only.. Different blank dialectic materials disposed at varying thicknesses in the wafer stack may require different combinations of power, pressure, flow, and temperature. The principles in the present invention specifically contemplate all such combinations.

The present invention has been particularly shown and described with respect to certain preferred embodiments of features thereof. However, it should be readily apparent to those of ordinary skill in the art that various changes and modifications in form and detail may be made without departing from the spirit and scope of the invention as set forth in the appended claims. In particular, the principles of the present invention specifically contemplate the incorporation of one or more of the various features and advantages taught herein on a wide variety of integrated circuit devices formed of varying wafer stack configurations defined by a number of different layers. The previously discussed process variables are of course capable of modification by those having skill in the art to effect different integrated circuit devices. Each of these alternatives is specifically contemplated by the principles of the present invention.

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